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BIOMETRIC STANDARDS FOR ENERGY REQUIREMENTS IN HUMAN NUTRITION

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ONE of the primary requisites in all of the exact sciences is the establishment of standard bases of comparison. For a decade the Nutrition Laboratory of the Carnegie Institution of Washington has been engaged in the precise investigations which must underlie the establishment of such standards in human nutrition.

This is an undertaking of the greatest practical importance. In times of peace, industrial efficiency and the physical well-being of the population demand exact knowledge of the amount and proportion of the different kinds of food which should be taken by the individual. If communities or nations are to be stringently rationed during periods of emergency, it is also necessary to know the minimum amounts of food required to maintain health and efficiency.

The problem is also one of great complexity. Aside from all questions concerning the chemical composition, digestibility and other physiological properties of the various foods, there are a large number of problems concerning the characteristics of human individuals which must be taken into account.

For example, it is obvious that those who are engaged in severe muscular work must consume larger quantities of food supplying energy than those who are less active. It might seem reasonable to suppose that larger individuals would require more food to carry on their normal activities than those who are physically smaller. It is a matter of common observation that older men and women demand smaller rations than those in the earlier stages of life.

All these questions require precise investigation before one is justified in drawing conclusions concerning them. If such investigations are to be used as a basis of recommendation concerning diet in peace or of regulation of diet in war, it is essential that the laws of energy transformation be expressed in a quantitative form.

Nutritional physiologists agree that, as far as energy is concerned, the food requirements of the living organism shall be expressed in calories per unit of time. Thus a physical standard is taken over from the quantitative sciences of physics and chemistry. Theoretically, then, the metabolism must be determined by placing the subject in a calorimeter and directly measuring the number of calories produced. This has been done in a large number of cases.

Since, however, the setting free of energy in the human body is merely a process of combustion, the measurement of the amount of oxygen consumed and the quantity of carbon dioxide excreted from the lungs should furnish a good index of heat production. Thus the nutritional physiologist may avail himself of the method of *indirect calorimetry* as well as of *direct calorimetry.* Heat production, in short, may be determined in a calorimeter or it may be computed from the gaseous exchange as measured in a respiration chamber.

The development of apparatus by which the heat production of the living organism may be directly measured in the calorimeter or by which the gaseous exchange may be precisely determined in the respiration chamber has occupied the attention of a large number of ingenious experimenters, among whom may be mentioned Lavoisier, Rubner, Zuntz, Atwater, Rosa, Lusk and Du Bois. The labors of these and others have brought the apparatus for the measurement of both heat production and gaseous exchange to such a high degree of refinement that the manipulative phases of nutritional physiology may be regarded as among the most exact techniques of biological experimentation. Extensive comparative studies have shown that, in the case of human subjects, it is much simpler and essentially as accurate to calculate the heat production indirectly from the gaseous exchange than to measure it in the calorimeter.

The problem is not, however, solely one of physical and chemical measurement. A number of biological factors must be taken into account. Muscular activity and the stimulatory action of recently ingested food are of chief importance. The apparatus with which students of human nutrition now work has been brought to such a stage of perfection as to measure the energy transformation accompanying such slight muscular activity as that required in the raising of the hand from the side to the mouth. The cost in calories of masticating food may be directly measured. For example, recent studies at the Nutrition Laboratory by Carpenter and Benedict have shown that the muscular work in chewing gum may increase heat production approximately 17 per cent. The difference between the heat production of a new-born infant asleep in its basket and crying can be precisely measured. Thus Talbot and Benedict found that the metabolism of the new-born infant is increased on the average by 65 per cent. in crying with its attendant muscular activity. Students of animal nutrition have long realized that the demands for energy of an animal standing are far higher than that of the same beast lying down. This fact must be taken into account in computing the maintenance requirements of cattle and other domestic animals.

Heat production is greatly increased after eating, and the amount of the increase is closely dependent on the nature of the food consumed. For example, the metabolism of a subject may be increased by 25 per cent. after a meal consisting chiefly of carbohydrates, but by as much as 45 per cent. after a heavy protein meal.

It is necessary, therefore, to eliminate all such factors in determining the standards which shall serve as bases of comparison in applied nutritional physiology.

Since the outbreak of the war, and particularly since our own participation in the conflict, the Nutrition Laboratory has, in addition to extensive investigations on the influence of subnormal rationing upon health and efficiency, pushed forward as rapidly as possible its work on the establishment of nutritional standards. One phase of this program has been the statistical investigation of the so-called basal metabolism of the human individual.[1]

Physiologists have gradually come to a general agreement that the heat production at complete muscular repose and in the post-absorptive state—*i. e.*, about twelve hours after the last meal—shall be called the basal metabolism and shall be used as a standard of comparison in the investigation of all the special problems of human nutrition.

[1] The detailed measurements and the statistical constants, with full discussions of pertinent literature, are about to appear in Publication 279 of the Carnegie Institution of Washington. We shall not, therefore, burden this brief outline with references to literature or statistical detail. Two of the diagrams used here are redrawn from this publication.

For several years the Nutrition Laboratory has been engaged in the measurement of basal metabolism in normal human individuals of both sexes and of widely different ages. These have been made with all the modern refinements of method and manipulation. The subjects were in presumably good health. All those with febrile temperature were rejected. All were in the post-absorptive condition. Perfect muscular repose during the short periods required for indirect calorimetry was assured by instruments providing an automatic record of all movements, even those imperceptible to trained observers.

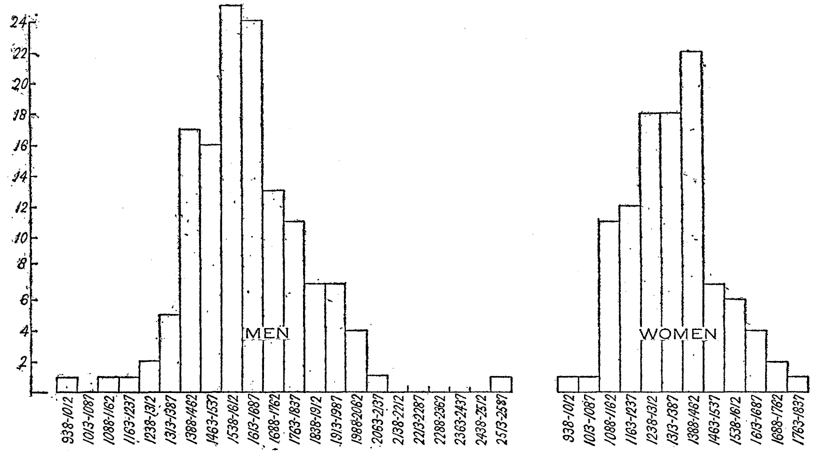

FIG. 1. FREQUENCIES OF MEN AND WOMEN PRODUCING VARIOUS NUMBERS OF CALORIES PER TWENTY-FOUR HOURS.

In carrying out a biometric analysis of the measurements which have been made on 136 men, 103 women, and 94 newborn infants, we have proceeded on the conviction that the widest possible usefulness of laboratory investigations of normal human metabolism will result from basing measurements upon those in presumably good health but otherwise typical of human beings in general. It is only when the subjects used for experimentation are representative of the population at large in type, variability and correlation that the results of laboratory research upon limited series may be safely generalized for rationing or for other practical social applications. An explanation of the statistical tests which have been applied to determine the suitability of the series used in the present investigation would lead us into too great detail for this discussion.

The average basal metabolism per twenty-four hours is as follows:

For 136 men	1631.74 calories.
For 103 women	1349.19 calories.
For 51 male infants	144.55 calories.
For 43 female infants	140.37 calories.

Thus it appears that the basal energy requirements of the American men are a little less than one half of the number of calories (3,300) established by the Inter-Allied Scientific Food Commission as necessary for rationing in the case of men doing average work eight hours per day. They are a little less than half the 3,200 to 3,600 calories used by a group of men at the Springfield Y. M. C. A. college before they were subjected to rationing tests by the Nutrition Laboratory. The average for new-born infants is somewhat less than ten per cent. of that of women.

Human beings differ in their basal metabolism just as they do in stature, weight, pulse-rate and other measurable characters. For example, the 136 men and 103 women showed the daily caloric output represented by Fig. 1. In these polygons the ordinates represent the frequencies of total heat production in calories per twenty-four hours.

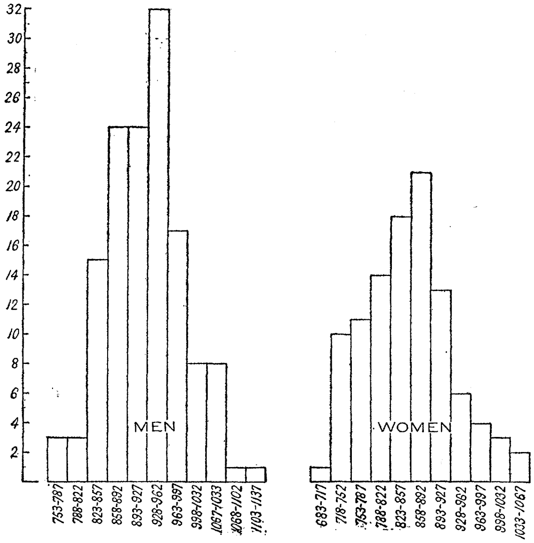

FIG. 2. FREQUENCIES OF MEN AND WOMEN PRODUCING VARIOUS NUMBERS OF CALORIES PER SQUARE METER OF BODY SURFACE PER TWENTY-FOUR HOURS.

The distribution of daily heat production in men and women is represented by monomodal, more or less symmetrical frequency polygons. This result is of considerable interest since it shows that the distribution of the magnitude of human basal metabolism exhibits the same orderliness that biometric work has shown to prevail in the variation of other biological measurements. When data are somewhat more numerous, it will be profitable to carry the analysis further by fitting theoretical frequency curves to these frequency distributions.

Measured statistically, the variability of these subjects may be expressed by standard deviations of 204.66 calories in men and of 155.18 calories per twenty-four hours in women, or by coefficients of variation, *i. e.*, of standard deviations expressed as percentages of the means, of 12.54 per cent. in men and of 11.50 per cent. in women.

The statement that variation in the total daily heat production of adults is measured by a coefficient of 11.5 to 12.5 per cent. will mean very little to the non-statistical reader until he can compare these with coefficients for characters with which he is more familiar. In our series stature shows a coefficient of variation of 4.39 in men and 3.20 in women, body weight a coefficient of variation of 16.06 in men and 20.35 in women, pulse rate at complete rest a coefficient of variation of 10.99 in men and 12.01 in women. Thus basal metabolism shows a variability far greater than stature but less than body weight and of roughly the same order of magnitude as pulse rate.

Basal metabolism is, therefore, rather highly variable. The reader will have noted, however, that the foregoing polygons and constants are based upon the total daily heat productions of adults in presumably good health but of various body weights, statures and ages. It has already been suggested that basal metabolism is related to these physical characters.

We must now inquire whether the observed variability in heat production is due in part to differences in bodily dimensions. This influence has been considered so great that some physiologists have asserted that heat production per square meter of body surface is a constant.

That heat production expressed in calories per square meter of body surface is not a constant in any exact sense is shown by Fig. 2, in which the ordinates represent the frequencies of total heat production per square meter of body surface as estimated by the Du Bois height-weight chart.

These diagrams show clearly that heat production per square meter, like total daily heat production, is a variable function. In both cases the frequencies decrease as the magnitudes of the constants diverge more widely, in both the plus and the minus direction, from the average for the whole series.

The fact that a large variability in daily heat production remains when it is reduced to calories per square meter of body surface does not, however, warrant the conclusion that metabolism is independent of bodily dimensions.

To investigate this problem we have merely to group all individuals according to some physical character and to determine whether metabolism changes with variation in the magnitude of the selected physical dimension. For example, Fig. 3 is made by representing the stature and the heat production of each individual on the horizontal and the vertical scales by a dot. It will be seen at a glance that the metabolism of men of any stature is highly variable. Nevertheless there is an orderly trend in the swarm; there is a marked tendency for taller men to show greater daily heat production.

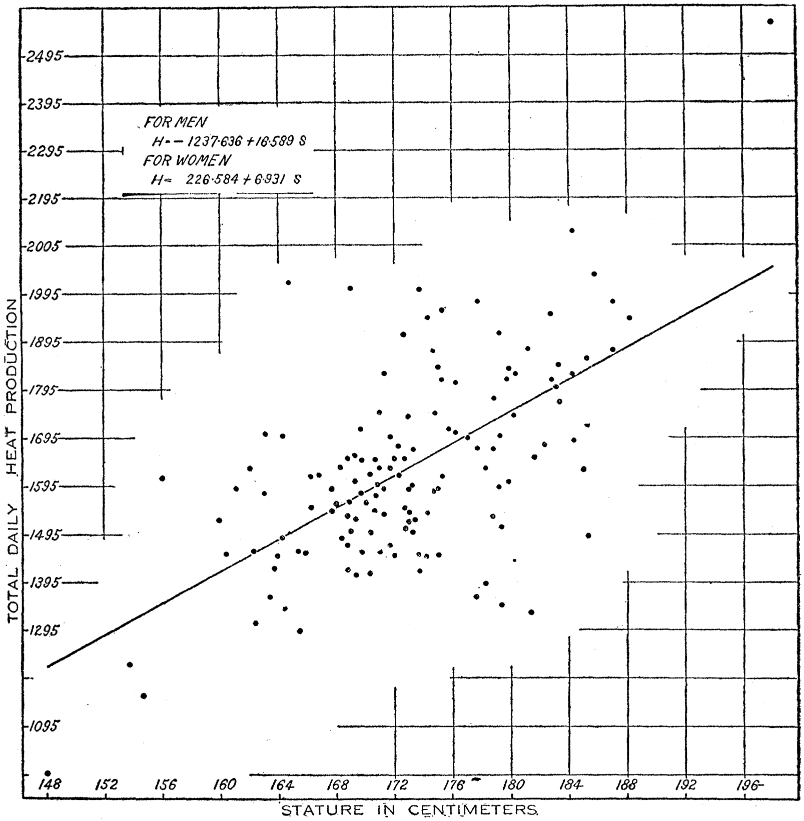

FIG. 3. RELATIONSHIP BETWEEN STATURE AND TOTAL DAILY HEAT PRODUCTION IN 136 MEN.

Such relationships may be represented in a different way. Take another physical character for purposes of illustration. One may determine the average daily heat production of individuals of different body weights, represent these averages by a series of points and smooth them with a straight line. Thus Fig. 4 shows quite clearly that the daily heat production of individuals tends to increase in a sensibly linear manner with their mass.

For exact comparison we must have recourse to some precise method of expressing the degree of relationship between physical characters and basal metabolism. This may be done by the use of the coefficient of correlation which measures the degree of interdependence of two variables on a universally comparable scale of unity. We find the values for the correlations between stature, body weight and body surface on the one hand, and total daily heat production on the other given in the accompanying table.

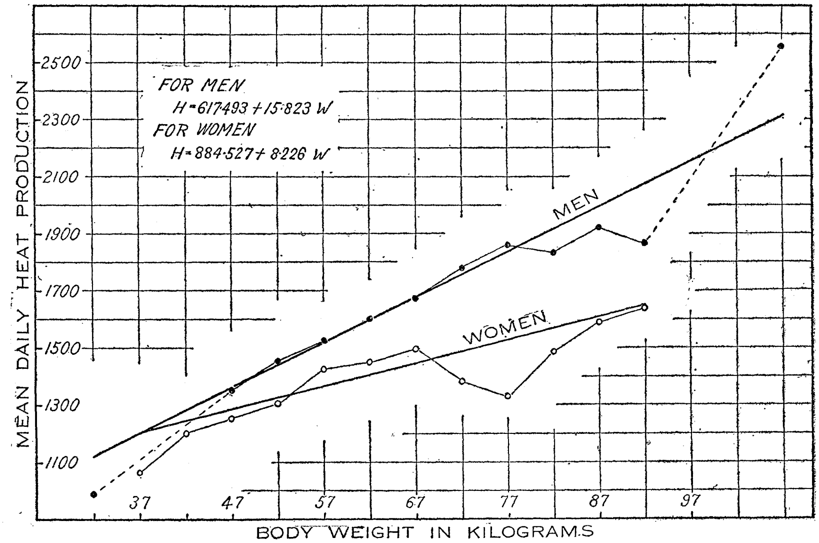

FIG. 4. RELATIONSHIP BETWEEN BODY WEIGHT AND DAILY HEAT PRODUCTION. Actual averages and fitted straight lines.

Series	Stature and Total Heat-production	Body-weight and Total Heat-production	Body-surface and Total Heat-production
Men (136)	+ 0.615 ± 0.036	+ 0.796 ± 0.021	+ 0.820 ± 0.019
Women (103)	+ 0.232 ± 0.063	+ 0.609 ± 0.042	+ 0.611 ± 0.042
Male infants (51)	+ 0.619 ± 0.058	+ 0.752 ± 0.041	+ 0.749 ± 0.042
Female infants (43)	+ 0.743 ± 0.046	+ 0.808 ± 0.036	+ 0.809 ± 0.036

The coefficients measuring the relationship between body weight and metabolism are in all cases higher than those between stature and metabolism. Body mass is, therefore, a more important factor in determining (in the proximate but not necessarily in the causal sense) the basal daily heat production of the individual than is a linear bodily dimension such as stature. The correlations between body weight and metabolism and between body surface and metabolism are of approximately the same magnitude. The two characters have, therefore, the same value in indicating the basal metabolism of the subject.

We have just noted that metabolism is correlated with both stature and body weight. Heavier and taller individuals have a larger daily food requirement. But body weight and stature are correlated characters. The interesting question, therefore, naturally arises whether the greater heat production of tall individuals may not be merely the resultant of the relationships between stature and weight on the one hand and weight and metabolism on the other.

This question may be solved by the use of appropriate partial correlation formulæ. We have to determine whether there is a correlation between body weight and daily heat production when correction has been made for the influence of stature, and conversely, to determine whether there is a correlation between stature and daily heat production when correction is made for the influence of body weight. The results are given in the accompanying table.

Series	Correlation Between Weight and Total Heat-production			Correlation Between Stature and Total Heat-production		
	Gross Correlation	Corrected for Stature	Difference	Gross Correlation	Corrected for Weight	Difference
Men (136)	+0.796 ±0.021	+0.687 ±0.031	+0.109	+0.615 ±0.036	+0.321 ±0.052	+0.294
Women (103)..	+0.609 ±0.042	+0.580 ±0.044	+0.029	+0.232 ±0.063	+0.045 ±0.066	+0.187
Male infants (51)...	+0.752 ±0.041	+0.549 ±0.066	+0.203	+0.619 ±0.058	+0.095 ±0.094	+0.524
Female infants (43)...	+0.808 ±0.036	+0.494 ±0.078	+0.314	+0.743 ±0.046	+0.149 ±0.101	+0.594

Since the partial correlation coefficients have sensible positive values, it is evident that both stature and body weight have independent significance in indicating daily heat production. This is a result of great importance, since it underlies the determination of the best formulæ for the prediction of the basal metabolism of the individual.

Let us now consider the relationship between metabolism and age.

The change in the food requirements of the human individual with age is not merely a question of material importance to the clinician, but of great interest to the biologist in its bearing upon the general problem of senescence.

The decrease in basal metabolism with age during the period of adult life has been shown to be well represented by the linear equations.

For men ($N = 136$),

$h = 1823.80 - 7.15\,a$, $h_k = 28.703 - 0.112\,a$, $h = 1022.17 - 3.60\,a$.

For women ($N = 103$),

$h = 1420.47 - 2.29\,a$, $h_k = 28.308 - 0.124\,a$, $h = 924.25 - 2.96\,a$.

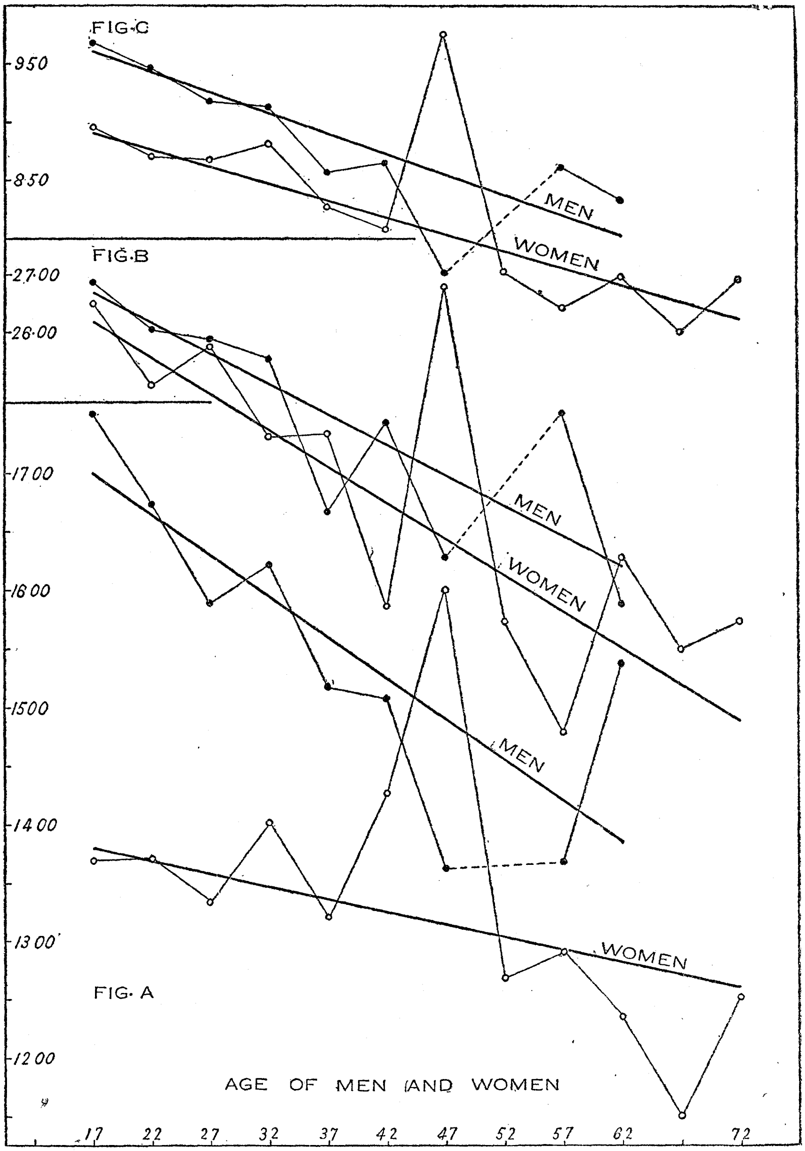

FIG. 5. DECREASE IN METABOLISM WITH AGE IN MEN AND WOMEN. Fig. *A* shows the decrease in total daily heat production, *B*, the decrease in calories per kilogram of body weight and *C*, the decrease in calories per square meter of body surface. The straight lines are due to the equations given in the text.

where h = total heat production in calories per twenty-four hours, h_k = calories per kilogram of body weight, h^D = calories per square meter of body surface, as estimated by the Du Bois height-weight chart. These lines are represented in the three diagrams of Fig. 5. While the actual mean heat productions are distributed about these lines with very great irregularity because of the small number of individuals (considered from the statistical, not from the physiological, side) it is doubtful whether equations other than those for straight lines could be advantageously employed.

These equations show that in men the daily heat production decreases about 7.15, while in women it decreases about 2.29 calories per year. Women are smaller than men and have a lower heat production. When the decrease in metabolism with age is expressed in calories per kilogram of body weight or in calories per square meter of body surface, the results for the two sexes are more nearly identical. The linear nature of the change in metabolism with age during the period of adult life fully substantiates the conclusions of biological writers concerning the greater continuity of senescence in the vertebrates as compared with lower organisms. It also shows that during adult life senescent changes take place at a sensibly uniform rate.

Throughout the entire history of the investigation of the metabolism of the warm-blooded animals, the question of the relationship between the body surface area of the organism and its heat production has been a center of interest. Even before the development of adequate experimental methods of investigating the energy transformation which takes place in the body of the vertebrate organism, the possible relationship of body surface area to heat production was a subject of speculation. Physiologists recognized that a whale or an auk in the arctic exposes relatively far less surface for the loss of heat than a flying fish or a humming bird in the tropics. Attempts were consequently made to explain the relatively higher food requirements of small as compared with large animals by the relatively larger surface exposed for heat loss in small organisms.

Newton's law of cooling made a strong appeal to the imagination of earlier physiological writers. It is not surprising that, impressed as they were by the relative constancy of body temperature in the warm-blooded animals, they conceived of heat production as proportional to heat loss as a means of maintaining constant body temperature, and came to look upon heat loss as determined by body surface area, and to consider heat loss as determining in its turn heat production.

This is not the place to trace the history of the so-called body surface law, according to which heat production per square meter of body surface is a constant. It has been widely maintained since the days of the speculative writings of Bergmann, the comparative studies of Rameaux, and the experimental investigations of Müntz, Rubner and Richet. Of recent years this so-called law has assumed practical importance in that writers have maintained that the closest approximation to the basal metabolism of a subject is given by

$$h = \bar{h}_s s,$$

where h is the required daily heat production, $\bar{h}_s$ the average heat production per square meter of body surface in a standard series and s the body surface of the subject under consideration.

The reader may be inclined to inquire why such a formula is of practical significance. The answer should be evident on a moment's reflection. Suppose the clinician wishes to investigate the influence of some disease, for example diabetes, on the metabolism. A subject is selected from the hospital ward, placed in the respiration chamber, and his daily heat production determined. This is merely a technical matter. The interpretation of the result presents a much more serious problem. The caloric output of the subject in a pathological state has no significance as indicating the influence of disease upon metabolism until it can be compared with a normal value. With what normal constant shall it be compared? Naturally, with that which would be expected for the same individual in good health. Thus the *theoretical* metabolism of the subject in health must be taken as a basis of comparison for his actually measured metabolism in disease before one can draw any conclusions whatever concerning the influence of the disease.

Again, suppose that stringent rationing is under consideration. What ration shall be allotted to individuals of various sizes? Clearly, both the most just and the most advantageous procedure would be to allow them food proportional to their physical needs.

Now one of the crucial tests of the validity of a law is its capacity for predicting the unknown. If the "body surface law," expressed by the above formula, serves to predict the heat production of a subject more precisely than any other formula, it must certainly take its place as one of the most important empirical laws in nutritional physiology.

This problem has been investigated in great detail in the extensive data collected at the Nutrition Laboratory during the past decade. These are now so numerous that it is possible to use one fraction of the records as a basis of prediction equations, and to test the validity of these equations by considering the metabolism of other actually measured individuals as unknown, calculating their caloric output by the various methods, and determining which formula gives the closest prediction. That formula which estimates the metabolism most exactly from measurable physical characters must be looked upon as the most valuable empirical law.

It must be admitted that the "body surface law" has given excellent results. If, however, there be no purely physiological basis for assuming a causal relation between body surface and heat production it would seem desirable, if possible, to replace this formula by a more rational one.

The foregoing analysis has shown that weight, stature and age all have independent significance for predicting the metabolism of the individual. Availing ourselves of the constants showing the independent relationship between these easily ascertainable characters and metabolism, we deduce the following multiple prediction equations:

For men $h = 66.473 + 13.752\,w + 5.003\,s - 6.755\,a.$
For women $h = 665.096 + 9.563\,w + 1.850\,s - 4.676\,a.$

where $w =$ body weight in kilograms, $s =$ stature in centimeters, and $a =$ age in years.

These equations make possible the closest prediction of the daily caloric output of an unknown subject. They are particularly well adapted to practical work. To calculate the most probable metabolism of any subject it is only necessary to substitute the actual values of weight, stature and age in the equation; for example, A. S. F. is a man 21 years old, weighing 69.3 kilograms, and 169 centimeters in height. His most probable daily heat production will therefore be given by

$$h = 66.973 + (13.752 \times 69.3) + (5.003 \times 169) - (6.755 \times 21) = 1723 \text{ calories.}$$

His actually measured heat production was 1,733 calories, or there was an error of only 10 calories per twenty-four hours or of 0.6 per cent. in predicting his metabolism from two physical characters and age.

The result is unusually good. K. G. M. is 32 years old, weighs 68.8 kilograms and is 171 centimeters tall. His daily heat production should, therefore, be given by

$$h = 66.473 + (13.752 \times 68.8) + (5.003 \times 171) - (6.755 \times 32).$$

The equation gives 1,652 calories as compared with 1,889 calories actually measured. This is an error in prediction of 237 calories, or of 14.3 per cent., and is next to the worst result secured by the use of our formula in a series of thirty-one tests on subjects measured subsequent to its development. For only five of the thirty-one individuals was the error of prediction over ten per cent. The average computed heat production of the 31 subjects was 1,661.03 calories per day, whereas the average measured heat production was 1,653.35 calories, or 7.68 calories per day less. If the individual differences between the observed and the measured heat productions be considered without reference to sign, *i. e.*, without regard to the fact that some are too low, whereas others are somewhat too high, we find that there is an average difference of ± 87.87 calories. Thus by the use of this biometric equation we have been able to predict the heat production of a series of subjects from two physical characters and age alone with an average plus or minus error of only 5.30 per cent.

We may illustrate the practical application of such multiple prediction equations[2] in clinical calorimetry by the values of

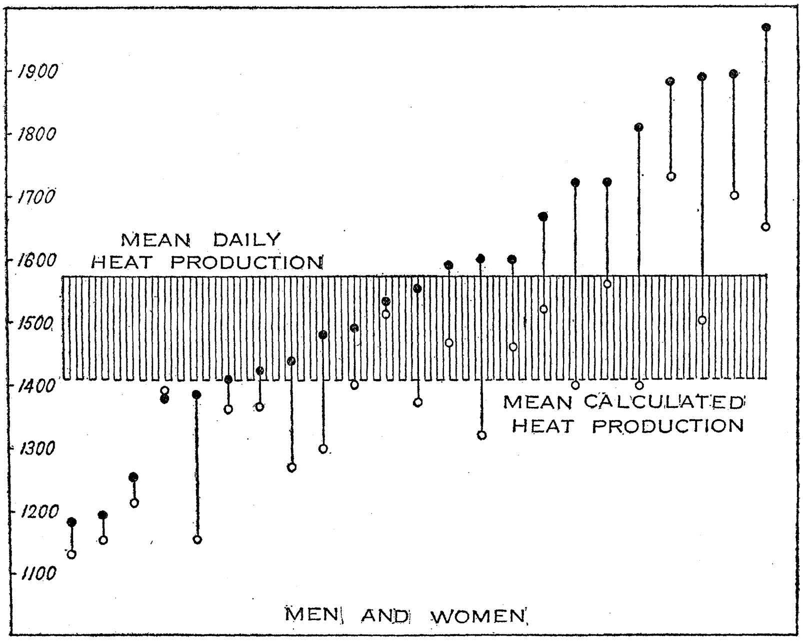

FIG. 6. COMPARISON OF METABOLISM OF DIABETICS WITH NORMAL STANDARDS.

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[2] These equations have been tabled for values of weight from 25.0 to 124.9 kilograms, for stature from 151 to 200 centimeters and for age from 21 to 70 years. Thus the most probable basal metabolism of an unknown subject may be easily determined.

the daily heat production of a series of 23 diabetic subjects investigated by Joslin and Benedict. These are represented on the scale at the left by the position of the solid dots in Fig. 6. The patients are arranged in order according to the magnitude of their daily heat production. The values given by the equations are represented by the position of the circles. In every case but one the metabolism of the diabetic is greater than that which would be expected for a healthy subject of like physique and age. The solid and the broken lines show the averages of the actual and the control heat productions. The average of the actually determined values is about 1,572.2 calories, or 11.55 per cent. higher than the average of the standard controls which is 1,409.4 calories. The influence of diabetes on the basal metabolism is clearly demonstrated.

As another illustration of the usefulness of these equations we may take the data for a series of twenty-two vegetarians, eleven men and eleven women, studied by Roth and Benedict. The question at issue is: Does, or does not, a vegetarian diet modify the basal metabolism?

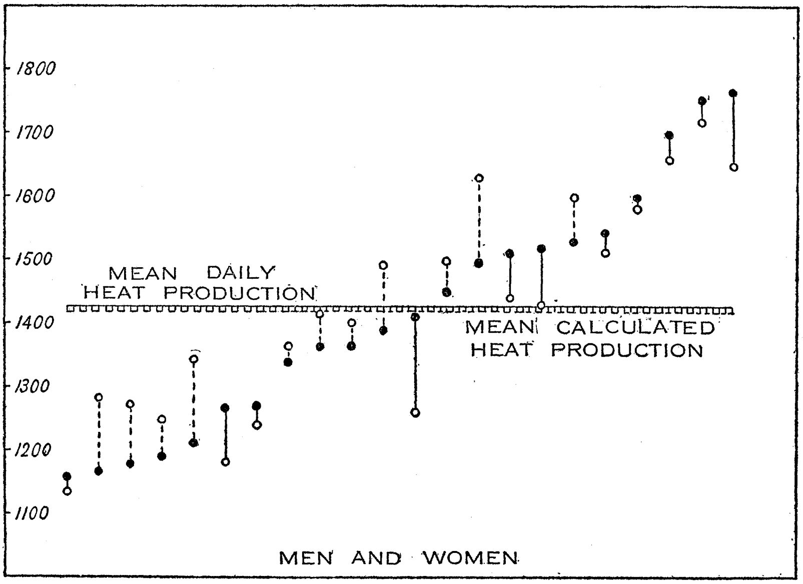

Fig. 7. Comparison of the Metabolism of Vegetarians with Normal Standards.

Fig. 7 shows the actual heat productions (solid dots) and the computed heat productions (circles) of the men and women. Since the equations used in computing the predicted values are for men and women respectively the two sexes may be treated together. In eleven cases the actual heat productions are higher, while in eleven cases they are lower than the values computed from the equations. The means of the actual and computed heat productions are practically identical. These results show clearly that there is no appreciable influence of vegetarian diet on the basal metabolism.

Other illustrations might be given. Perhaps the most interesting is the use of the equations in investigating the difference in the metabolism of men and women. This problem, which has attracted the interest of a number of investigators in the past, has been reconsidered from all sides on the larger series of data now available. The results show that the average daily (twenty-four hours) basal heat production of the 136 men investigated is 1,632 calories, whereas that of the 103 women studied is 1,349 calories. Thus the daily heat production of women is about 300 calories less than that of men. But women are smaller than men. If correction for body size be made by expressing heat production in calories per kilogram of body weight, it is 25.7 calories in the men as compared with 24.5 calories, or 1.2 calories per kilogram less, in the women. The men show an average daily heat production per square meter of body surface of 925 calories as compared with 850 calories, or 75 calories less, in the women.

The most critical test of the existence of a difference in the metabolism of men and women is that furnished by comparing the actually measured metabolism of women with that calculated from biometric equations on the assumption that they are men of like stature, weight, body surface, age or combinations of these characters. The diagrams in Fig. 8 show the differences between the actual metabolism of women (circles and lower lines) and the heat production calculated on the assumption that they were men of comparable physical characters and age (solid dots and upper lines). Diagrams *A–C* represent the results given by three different equations. The shaded zone shows a deficiency in the actual heat production of the women, who are classified according to body weight, throughout.

These and further statistical tests which can not be discussed in detail show conclusively that the metabolism of American women is lower than that of men. Our results show that the differentiation of the sexes is not evident in infancy. They do not confirm the conclusion of Sondén and Tigerstedt that the difference between men and women tends to disappear with age. Instead we find the difference in the metabolism of men and women well marked throughout the period of adult life.

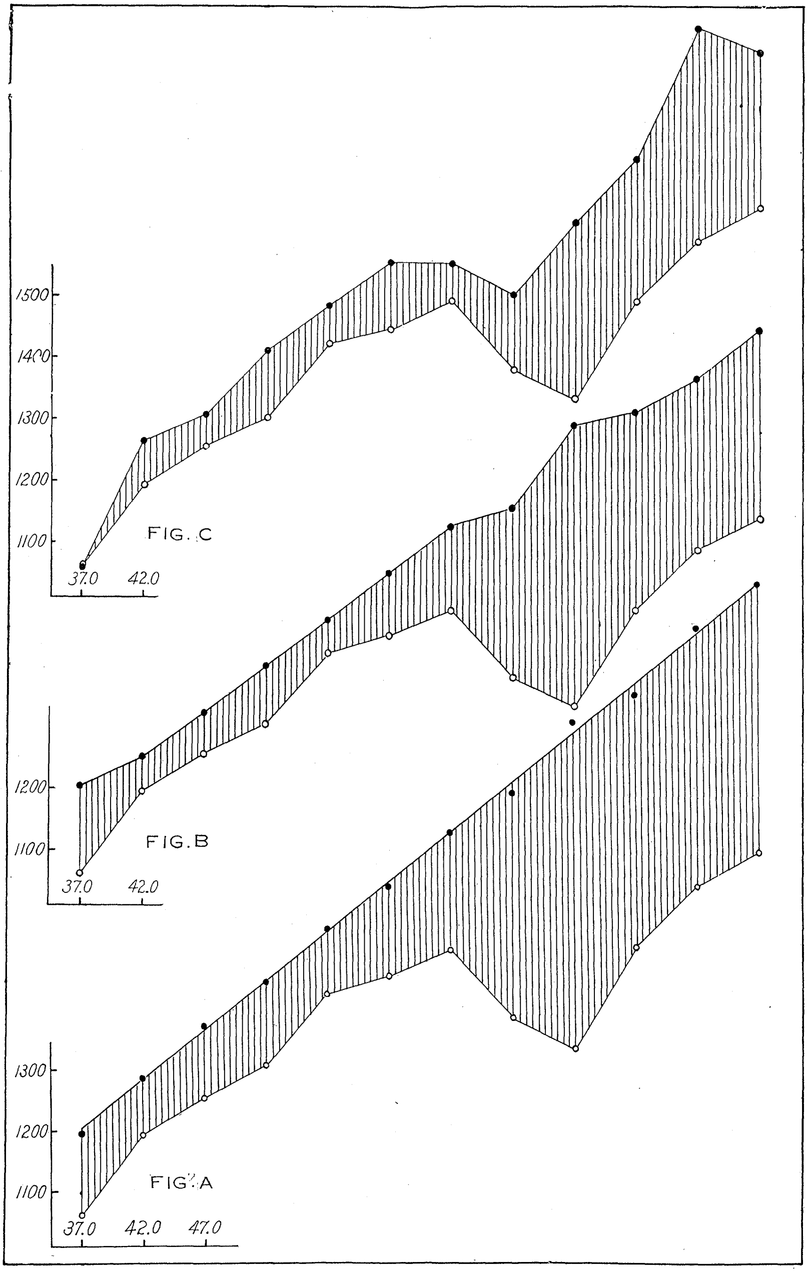

FIG. 8. COMPARISON OF METABOLISM OF MEN AND WOMEN.

This brief outline may serve as an introduction to some of the problems which require consideration in the establishment of normal standards for work in human nutrition.

It would be quite unfair to leave the reader with the impression that the basal metabolism is a fixed and unchangeable physiological constant. While extremely valuable as a basis of comparison, the basal metabolism is subject, not only to great variation from individual to individual, but to modification in response to profound experimentally induced changes in the level of nutrition of the subject. Thus a man who underwent a 31-day fast at the Nutrition Laboratory, during which he took no food whatever and only about 900 cubic centimeters of distilled water per day showed a decrease of 28 per cent. in his basal metabolism.

A more recent investigation of the influence of severely limited diet, undertaken by the Nutrition Laboratory on squads of men who volunteered for this purpose at the International Y. M. C. A. College at Springfield, Mass., in response to the need for more exact information concerning the influence of war-time diet on health and efficiency, has shown a striking influence of reduced diet accompanied by rapid alteration of body weight on the basal metabolism. One squad was kept for a period of four months on a restricted diet with an energy content of one half to two thirds of the requirements prior to the fast, when the normal demand of the men ranged from 3,200 to 3,600 net calories. After a reduction of only 12 per cent. in weight, 1,950 calories only were required to maintain this weight.

Notwithstanding this fact, and the wide variability in basal metabolism in whatever units it may be expressed, the basal metabolism when measured on large numbers of individuals in good health and living under normal conditions, and described in terms of the proper biometric constants and equations, furnishes a valuable, and as yet the only available, standard of comparison in the investigation of all the special problems of energy requirements in human nutrition.